Improving Service Quality Parameters using the ant Colony Algorithm in MANTE Network

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Abstract

mobile ad hoc network (MANET) are a number of devices such as mobile phones, personal digital devices or laptops that wirelessly form a network together without the use of centralized components such as routers. One of the existing protocols for routing in MANET is the Ad hoc On-Demand Distance Vector Routing (AODV), in which the nodes have the status of the neighboring nodes in the form of a routing table. The AODV protocol has features such as creating a route when needed, as well as good performance in MANET case. But this protocol does not scale well for large networks where the number of nodes and the traffic volume are large. The mentioned problem causes quality of service parameters such as bandwidth, delay, end-to-end delay, throughput, routing overhead, and Packet loss in this protocol do not work well. One of the solutions to solve the problems is to use meta-heuristic algorithms. Among the meta-heuristic algorithms, Ant Colony Algorithm is considered because the nature of routing can be seen in it. We continued to improve the quality of service parameters by using the ant colony algorithm, which has improved the performance of MANET. According to the results of the conducted researches, it is possible to use the ant colony meta-heuristic algorithm to improve service quality parameters in MANET. This method can improve the performance and satisfaction of users and in finally lead to the overall improvement of MANET.

Keywords: MANET, AODV, ACO,QOS

Introduction

MANET are a number of devices such as mobile phones, personal digital devices or laptops that wirelessly form a network together without the use of centralized components such as routers. The nature of this network is more similar to a peer-to-peer network where each node can act as a client or server. In addition, each node can be a router for itself that can measure the best route to the destination. Thus, there is no static topology or environment in a MANET, and any node can suddenly leave or join the network. According to the above mentioned, one of the existing protocols for routing in MANET is the Ad hoc On-Demand Distance Vector Routing (AODV), in which the nodes have the status of the neighboring nodes in the form of a routing table. This table helps to find the path from the source to the target nodes. It allows the required packets that contain information to be sent. AODV protocol has features such as route creation when needed and also good performance in mobile wireless ad hoc networks. But this protocol is vulnerable to various types of attacks such as black hole attacks, spoofing attacks, and does not scale well for large networks where the number of nodes and traffic volume are large. The mentioned disadvantages cause quality of service parameters such as bandwidth, delay, End-to-end delay, throughput, routing overhead, packet loss, etc. do not perform well in this protocol. In the discussion of routing, there is not always an absolute route and the route is always changing, according to this issue, one should use an algorithm that can reach the optimal answer, but this answer is not definitive. One of the solutions to solve problems that do not have a definitive answer is the use of meta-heuristic algorithms. Among meta-heuristic algorithms, the ant colony algorithm has been noticed because the nature of routing can be seen in it, so we want to use this algorithm in this work to solve problem and improve quality of service parameters.

Mobile ad Hoc Network

MANET is a number of devices such as mobile phones, personal digital assistants or laptops that create a network wirelessly without using centralized components such as routers or access points, the figure 1 shows a mobile ad hoc wireless network and its components. The nature of this network is more similar to a peer-to-peer network where each node can act as a client or server, in addition, each node can measure the best route to the destination for itself as a router. Thus, there is no convergence or static environment in MANET and any node can join or leave the network suddenly. Nodes in MANET require a very small amount of processor, energy storage, and memory, so they are usually light in weight. There are two wireless network models, one with fixed infrastructure and the other with non-fixed infrastructure. In a fixed infrastructure network, there is a central coordinator called an access point through which communication between nodes is established [1]. The disadvantage of these types of models is the high overhead of maintaining routing tables. In a network without a fixed infrastructure, there is no central coordinator for communication between nodes, and is called MANET. In environments with a lack of communication infrastructure, it seems necessary to use MANET [2]. In some cases, the existing infrastructure cannot work well to transmit data between members, so a MANET should be designed and presented as a solution. MANET can work alone or on the Internet. Nodes in these networks play the role of transmitters and receivers. And a path may contain one or more transmitters from the source to the destination. The problems of MANET are dynamic topology changes, limited energy consumption and no existing infrastructure support. Also, another problem of this type of networks is the malicious node, the purpose of a malicious node is to disrupt the routing protocol that is implemented in the network. Therefore, you need quality of service parameters. quality of service is also defined as the collective effect of service performance that determines the level of satisfaction of service users. Each node in the network sends and receives data in packets and also forwards data to other nodes in the network. Various applications of this network include disaster relief operations, military sector, sensor networks, wireless mesh networks, etc. Also, in order to achieve a real sense of communication around the world, sometimes the only solution is a MANET to communicate with the rest of the world and fill the digital gap of satellite. Therefore, the satellite is not only used as a part of an alternative routing path, but also considered as a part of the integrated MANET system. There are many types of attacks on MANET and according to the attack technique, they can be classified into two main categories, i.e. passive attacks and active attacks. One of the attacks is the black hole attack, which is one of the security threats. A black hole attack is a network layer attack. In this attack, a malicious node mistakenly sends the most stable route to the destination node during route discovery. After receiving the route request from the malicious node, the source node sends the packets to the malicious node. After receiving the packets from the source node, the malicious node drops the packets instead of sending them to the destination nodes. The goal of the malicious node is to disrupt the routing process and drop almost all packets. Black hole attack is a serious threat to the security of MANET. Nodes in a MANET must cooperate with each other and connect through each other for specific tasks such as routing [3] . MANET has a dynamic network and the connectivity between nodes may look different [4]. Over time, due to the movement of the node, the exit of the node and the emergence of a new node, routing protocols play an effective role in connecting nodes to each other [5]. In a mobile ad hoc network architecture, each node works as a router as it forwards packets for other nodes [4]. MANET architecture is divided into the main parts of active technologies, networking and middleware and application [5]. Also, MANET has features such as distributed operation, multi-step routing, spontaneous coordination and self-building, self-organization and self-management [4,5].
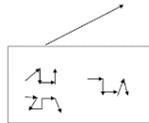

Figure 1

Motion models

Motion model is programmed to define user motion configuration. The mobility model in MANET is characterized by the mobility of the nodes. With the mobility of the nodes, their position, speed and acceleration change in time. Movement patterns may play an important role in defining protocol performance. Therefore, it is necessary for motion models to imitate the motion pattern. Also, it is important to choose the appropriate movement model to calculate the routing protocols in MANET. Motion models are divided into three categories [4]:

• Random Walk Model : Random walk model is also known as Brownian motion because some moving nodes move in an unexpected way. Each node moves from its current area to another area by arbitrarily choosing an optional path and speed within a certain range. Such movement is done in a fixed time or a fixed distance. This model is defined as a memoryless movement pattern because it does not retain any information about its previous location and velocity values.

The figure 2 shows an overview of this model.

Figure 2

• RWP Mobility Model : this model is used as a benchmark for evaluating MANET routing protocols due to its simplicity and wide availability. In this movement model, each moving node randomly chooses a place as a destination. Then it moves uniformly and randomly towards the destination with a constant speed. The speed and direction of a node is independent from other nodes. Once the destination is reached, the node stops for a while. After this time, it moves again to another random destination. The whole process is repeated over and over again until the simulation is finished. The figure 3 shows an overview of this model.
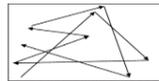
Figure 3

• Random direction model : the random direction model is able to overcome the problems of non-uniform spatial distribution. In this model, a direction is chosen randomly and based on that, the movement takes place uniformly. The figure 4 shows an overview of this model.
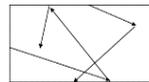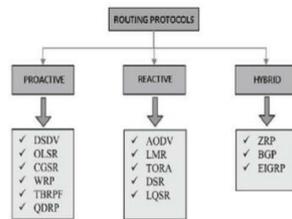

Figure 4

• Gauss Markov movement model : in this model, the movement depends on the current speed and direction of the node. The idea is to remove the sharp turns found in random walks and random waypoints while maintaining a certain degree of randomness. The figure 5 shows an overview of this model.
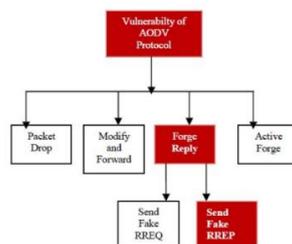

Figure 5

Routing Protocol

Routing protocols are a set of rules that control the path of message packets from source to destination in a network. The main goal of a MANET routing protocol is to set up an efficient path between nodes in order to deliver messages in time. Since nodes in the network have no prior knowledge of the topology, they must discover it. Furthermore, nodes tend to move freely and randomly, paths are often interrupted even after discovery. Therefore, it is a routing protocol that controls the discovery and maintenance of routes between computing devices in a MANET. The main idea of a routing protocol is for a new node to announce its presence and listen and respond to the announcements of its neighbors. These protocols in a MANET are mainly divided into three categories: active routing, reactive routing, and hybrid protocols. In the first category, active routing protocols are also called table-based routing protocols. In this protocol, each node stores a routing table containing information about the network. Although useful for datagram traffic, this feature incurs significant signaling traffic and energy consumption. Whenever the network configuration changes, the routing tables are regularly updated. Active protocols are not suitable for large networks because of maintaining a record for each node in the routing table. DSDV, OLSR, CGSR, WRP, TBRPF, QDRP protocols are examples of this category. The second category of reactive routing protocol in this protocol, the route is discovered when needed. Nodes adjust route discovery based on demand. The source node checks its route cache for an available route from the source to the destination, and if no route is available, it starts the route discovery process. DSR, AODV, LMR, TORA, LQSR protocols are examples of this category. And the third class of hybrid protocols inherits the characteristics of reactive and proactive routing protocols, and usually tries to take advantage of the reduced control traffic overhead of proactive systems. However, by maintaining some sort of routing table, they reduce the route discovery delays of reactive systems. ZRP, BGP and EIGRP protocols can be mentioned among the types of this category. The figure 6 shows an overview of the routing protocols category [5].

Figure 6

Ad hoc On-Demand Distance Vector Routing (AODV)

Ad hoc On-Demand Distance Vector Routing is a reactive routing in which each node has the status of its neighboring nodes in the form of a routing table. This table helps to find the path from the source to the destination nodes so that the required packets containing the information can be sent. Sequence number concepts are useful for identifying new routes in the network and avoiding the routing loop problem in AODV. The status of each node is managed by AODV by maintaining a row for each node in the routing table. If a row in this table has not been used recently, that row is deleted. The Route Reply packet is sent to the source node using the routing table. This table contains information about the previous nodes that the packet has passed through. If any link in the network goes down, previous nodes are alerted by RERR packets. In AODV, a node that wishes to discover a route to a destination node generates R_REQUEST route request packets. These packets are then broadcast to their neighboring nodes, which in turn rebroadcast the packets to their neighbors. This is repeated until an R_REQUEST packet reaches the destination node. When the destination node receives this R_REQUEST packet, it generates the R_REPLY path response packet and sends it to the source node through the reverse path. The R_REQUEST packet that reaches the destination node later is ignored. In AODV, intermediate nodes that have a destination request number greater than RREQ generate an RREP to identify new routes and send it to the source node. Each RREQ packet contains a time to live (TTL) value that specifies the number of times the RREQ packet should be rebroadcast. When each node receives the RREQ, it creates a reverse route entry in its routing table. This reverse route entry contains information such as the IP address of the source node, the sequence number, the number of hops to the source node, and the IP address of the neighbor node from which the RREQ was received. In this way, the destination node knows how to send the RREP to the source node, that is, the reverse route is used to send the RREP packet. During RREP transmission, the forward path is being set. Among the advantages of this protocol, we can point AODV is a reactive routing protocol, which means that it creates a route only when needed [6]. This reduces network overhead and preserves bandwidth. And this protocol is designed to work well in MANET, where nodes move frequently and connectivity changes rapidly. This protocol supports unicast and multicast routing, making it suitable for a wide variety of applications. It is also a loop less protocol, which means that it avoids the formation of routing loops. This protocol includes a mechanism to detect and manage link failures, which improves network reliability. And among the disadvantages of this protocol, it can be mentioned that it is vulnerable to various types of attacks such as black hole attacks and spoofing attacks. This protocol does not scale well for large networks with large number of nodes and high traffic volume. Also, the vulnerability of the AODV is shown in the figure 7. AODV is attacked in various ways, in some cases the intruder either drops packets, changes the message formats and then forwards it, or the attacker sends a spoofed message to the received routing message [6].

Figure 7

1-5 Metaheuristic Algorithms

Meta-heuristic algorithms are a type of stochastic algorithms that are used to find the optimal answer. These algorithms are part of the category of approximate algorithms that are able to find close to optimal solutions in solving problems. Approximate algorithms are divided into three categories of heuristic, meta-heuristic and super-heuristic algorithms. The two main problems of heuristic algorithms are their getting stuck in local optimal points and premature convergence to these points. Meta-heuristic algorithms are presented to solve these heuristic algorithm problems. The two main problems of heuristic algorithms are their getting stuck in local optimal points and premature convergence to these points. Meta-heuristic algorithms are presented to solve these heuristic algorithm problems. In fact, meta-heuristic algorithms are one of the types of approximate optimization algorithms that have solutions for exiting from local optimal points and can be used in a wide range of problems. Meta-heuristic algorithms are divided into four categories based on one answer and based on population, inspired by nature and without inspiration from nature, with memory and without memory, deterministic and probabilistic [7]. Among the well-known population-based meta-heuristic algorithms are evolutionary algorithms (genetic algorithm, genetic programming,...), ant colony optimization, bee colony, particle

swarm optimization method, forest optimization algorithm, championship algorithm in sports leagues, root-pajosh algorithm and He called the smart water drop algorithm [7] .

Metaheuristic Algorithm of ant Colony

The ant colony algorithm is inspired by the studies and observations on the ant colony. These studies have shown that ants are social insects that live in colonies and their behavior is more towards the survival of the colony. One of the most important and interesting behavior of ants is their behavior to find food, and especially how to find the shortest path between food sources and the nest. Ants deposit a certain amount of a pheromone chemical that acts as a path marker for successor ants.Initially, the ants choose a random route between the nest and the food. They can discharge a variable amount of pheromone trails along their route [7]. Assuming the deposited amount of secretion, the newer ant chooses the optimal path with higher concentration of secretion, which is the shortest path among all the remaining alternative paths. The pheromone concentration of the shortest path is greater than all the remaining paths [2]. In the event that an obstacle is placed in their path, the ants start the path discovery process again by randomly choosing the next hop until the ants converge on paths with a relatively higher pheromone concentration. Ant colony algorithm adopts a reactive probabilistic approach to find robust paths between source and destination [20]. At regular intervals, a search ant is launched with the mission of finding a path to the destination. When a node first receives a search ant, it creates an entry in its routing table. The input contains the destination address, which is the source address of the search ant, the search ant will most likely choose the next hop to reach the destination. The trailing ant creates the pheromone path from the origin to the destination. After calculating the selection probabilities, the node sends data packets to that neighbor node that has a relatively higher selection probability among its neighbor set. The selected relay nodes increase their pheromone amount to a certain amount. Like their natural counterpart, synthetic pheromones decay over time. The evaporation process provides a negative feedback in the system that helps the ant to avoid stale paths in the network. Evaporation of pheromones takes place continuously by reducing the amount of pheromone. When the data packet reaches the destination node, the method ends. Nodes maintain the neighbor's existence in their neighbor table by periodically sending Hello Packet to each other. Hello packet sending interval can be different according to different mobility scenarios. If a node does not receive the neighbor's Hello packet after a certain period of time, it deletes the neighbor's information from its neighbor table. The process of finding the shortest path by ants has very interesting features, first of all it is highly generalizable and self organizing. In addition, there is no central control mechanism [20]. The second feature is its high power. The system consists of a large number of factors that alone are unimportant, so even the loss of an important factor does not have a large effect on the system's performance. The third feature is that the process is an adaptive process. Since the behavior of none of the ants is certain and a number of ants still choose the longer route, the system can adapt itself to the changes in the environment and the last feature is that this process can be expanded and can be as large as desired. The pheromone substance wears off over time, making the trail less attractive to subsequent ants [7]. And since an ant in the long run travels more and reinforces shorter paths, any path between home and food that is shorter (better) is strengthened more. Also, if the pheromone did not evaporate at all, the paths that were taken multiple times would become so highly attracted that they would greatly limit random foraging. The advantages of the ant colony algorithm include finding optimal routes, identifying alternative routes, distributing traffic equally in different routes, avoiding congestion, fault tolerance, scalability and energy efficiency [7].Among the applications of this algorithm, we can refer to intra-city and inter-city routing, routing between high-voltage power distribution network posts, computer network routing, use of the web, use in optimizing water distribution networks [7-9].

Proposed Idea
Optimization by the Method of ant Colony Algorithm

As we know, the problem of finding the shortest path is an optimization problem that is sometimes very difficult to solve and sometimes very time-consuming. By performing a dynamic programming algorithm for this problem, the exponential time is obtained. Of course, other algorithms have been presented, but none of them have a suitable performance. The ant colony algorithm is a complete and suitable solution for solving the problem [8].

Short Path Finding by ants

Ants leave pheromone chemicals when they walk, when choosing between two paths, they will probably choose the path that has more pheromone. Or in other words, more ants have already passed through it. Now pay attention to how this simple arrangement will lead to finding the shortest path. As we can see in Figure 8, the ants are moving on the path (in two opposite directions). If we put an obstacle in the way of the ants (part 2), the ants have two ways to choose. The first ant comes from A and reaches C. It does not see any pheromones on the route, so it gives the same probability for the left and right routes. It randomly and probabilistically chooses the CED route . The first ant that follows the first ant reaches the destination earlier than the first ant that followed the CFD route. The ants are coming back and over time they feel a greater effect of the pheromone on the CED. And they choose it randomly. Finally, the CED route is chosen as the shorter route. In fact, because the length of the CED route is shorter, the round trip time is also shorter. And as a result, more ants will pass it than the other way because there is more pheromone in that way [8]. A very important point is that although the probability of ants choosing the path with more concentrated pheromone is higher, but this is still a possibility. That is, if the CED path of pheromone is thicker than CFD, it cannot be concluded that all ants will pass through the CED path. Rather, it can only be said that, for example, 90% of ants will pass through a shorter route. If we assume that there was certainty instead of this possibility, that is, each ant would only choose the more concentrated

pheromone path, then basically this method would not be possible to get the answer. If by chance the first ant chooses the CFD path (the farthest path) and leaves a trace of pheromone, then all the ants will follow him and the shortest path will never be found. Therefore, coincidence and probability play a major role in the ant colony algorithm.
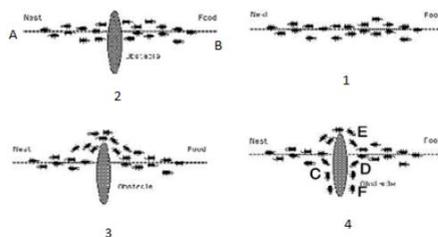

Figure 8

Ant Colony Algorithm Performance

Ant colony algorithm is a meta-heuristic algorithm. Ants in real life work together to find their way to their food source. Ant colony algorithm is one of the research directions used in crowd intelligence. Information exchange between ants is indirect and information exchange is done by pheromone. One of the positive feedbacks we get with the implementation of the ant colony meta-heuristic algorithm is that it describes a framework that can adapt to network changes in real time. And simultaneously several solutions are found for the considered problem [10]. Each ant in a network starts from a node S and goes to the destination node D. The simulated ants follow a probabilistic decision rule to discover the network. The decision rule is a function of local pheromone routes. The applied probability law is shown in formula number 1.

$$(1) \quad P_{ij}(t) = \frac{[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum 1 \in N_i [\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}} \, if \, j \in N_i, else \, 0$$

where $P_{ij}(t)$ is the probability of the ant moving from node i to j in iteration i, N_{ij} is the current neighbor nodes of node i, $\tau_{ij}(t)$ is the intensity of the pheromone, η_{ij} is the heuristic information, which is usually a non-increasing function of the movement cost. α and β are parameters that control the effect of pheromone intensity. When α = 0, the ant chooses its next step based on the heuristic information. And when β = 0, ants are attracted by the intensity of the pheromone. So it shows that ants can only move towards their neighboring nodes. Pheromones either increase or decrease pathways. The pheromone update is calculated based on the quality equation and the evaporation rate is shown in formula number 2 [8].

$$(2) \quad \tau_{ij} \leftarrow (1 - \rho).\tau_{ij} + \sum_{k=1}^{m} \Delta\tau^k_{ij}$$

While τ_{ij} is the amount of pheromone left by the ants, $\rho \grave{o} [0,1]$ is the evaporation rate of the pheromone, m is the number of ants, $\Delta\tau^k_{ij}$ is the pheromone booster left by the kth ant. The enhancement of pheromone can be evaluated using formula number 3.

$$(3) \quad \Delta\tau^k_{ij} = \frac{Q}{c^k} \, if \, arc(i, j) \in P^k \, else \, 0$$

While Q is a positive constant, P is the set of edges selected by k ants. C^k is the total cost function of the path constructed by k ants. There are many other variations in the ant colony algorithm that may have minor changes to the equation above in pathfinding and pheromone updating. But in general, the implementation of the ant colony algorithm includes three main functions of constructing the solution of the ants, the procedure in which the ants find the solution of constructing the graph. Pheromones update is a procedure where ants update the pheromone level and actions implemented to add focused actions, and it is also an optional procedure. One of the merits of the ant colony meta-heuristic algorithm is to provide a framework for solving problems with hard complexity.

Ad hoc On-Demand Distance Vector Routing (AODV)

AODV is a demand-based protocol whose working idea is based on source routing. MANET nodes need to maintain the route in the routing table that contains the source routes. The information entered in the routing table, which contains information about the available routes of the source, is updated as needed or on demand. This routing protocol has two phases. In the first phase, the route is discovered, in Figure 9, if the source has a route to the destination in its memory and wants to communicate with it, it immediately uses this route. But if there is no route to the destination, the route discovery process, which we will discuss below, begins. First, the source sends a route request packet to all nodes. If node A has already received the route request or its address is available in the route archive, this node deletes

the request. If node A is the target of route discovery, the node returns an answer packet to the route to the origin. The answer packet to the path contains the best path from the source to the destination. When the source receives this packet, it stores this route in its route memory to use it later. Otherwise, node A sends the resource request to its neighbors. In the second phase, the route is maintained, in AODV each node is responsible for confirming the receipt of the packet by the next node and also each packet is sent only once by each node. If a packet does not reach a certain node, the sending process continues for a certain time. If receiving the packet is not confirmed, a path error message is sent to the source and the desired path is deleted from the path memory. Then the source looks for another route from its route memory. And if there is no route in the memory, a route request packet is issued. Our proposed method is the first simplified version of AODV protocol. We use AODV avoiding some parameters like leading list, route error message etc. In addition, loops can be avoided by the route reply packet sent by the destination node. The proposed method is much simpler than AODV. It can be extended by implementing some optimizations to improve performance and some security features can also be added [11-15].
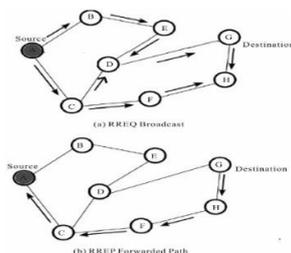
Figure 9

Energy Efficiency

In MANET, nodes work on limited power stored in themselves. If the implemented algorithm is designed in such a way that it is not energy efficient, the network may collapse. There is a very critical need to implement an energy-efficient algorithm that can save the energy of nodes and complete a process. Although nodes operate with limited energy, it does not mean that we cannot extend the lifetime of the node. In fact, the goal of energy efficient models in wireless networks is to save the energy of the nodes so that they can operate for a longer period of time and not disappear. In the absence of a base station, each node must participate in protocols such as routing, etc., to save energy. Nodes in these networks can change their transmission power levels to connect to the network, while simultaneously increasing network capacity, reducing energy consumption and interference. The evaluation of the total energy consumed by the network is given in formula number 4 .

$$(4) \quad E_{TOTAL} = E_{ECHO} + E_{RD} + E_{DATA}$$

where ERD is the energy consumed in the route discovery process, EDATA is the energy consumed during data transmission, and EECHO is the energy consumed by the broadcast message. The energy used in data transmission is evaluated according to formula number 5. where Eelec is the energy dissipated per bit to run the receiver circuit, γfs is the expanded energy when $d \leq d_0$ is , and γ_{mp} is the energy consumed in the amplifier when $d \leq d_0$, d represents the distance.(Fatemidokht and Kuchaki Rafsanjani 2018)

$$(5) \quad E_{TX} = \left[\begin{array}{l} B \times E_{elec} + B \times \gamma_{fs} \times d^2, if\, d \leq d_0 \\ B \times E_{elec} + B \times \gamma_{mp} \times d^4, if\, d \geq d_0 \end{array} \right]$$

Delay

Delay in MANET includes various types such as compression and decompression delay, processing delay, propagation delay, media access delay, acknowledgment and retransmission delay, jitter delay, end-to-end delay, and routing delay. End-to-end delay is a very important performance measure in MANETs, especially in real-time or multimedia applications. The increase in delay time can be due to congestion or collision, as well as other factors such as the length of the route and the level of interference on the route. However, it is important for this model of networks to avoid network congestion and collisions to optimize MANET throughput and performance in general. AODV is one of the most widespread demand-based (reactive) routing protocols used in table-oriented theory. This service is designed as a best effort and considers the minimum number of hops or the shortest path between the origin and the destination as the main criteria in determining the optimal routes. However, this protocol does not consider MANET dynamics. Such as topology changes due to nodes moving out of range and thus causing link failure or node failure, which in turn leads to incorrect delay estimation. In the meta-heuristic algorithm of the ant colony, we assume that for each link, the related service quality parameters are the same for both round-trip directions. Therefore, the path delay from the source node to the destination node is equal to the sum of all link delays [27].

$$(6) \quad D(p(s,d)) = \sum_{e \in p(s,d)} D(e)$$

Suggested Routing

In Figure 10, the pheromone is stored in the memory of each node as a matrix, where the neighboring nodes are listed on the row side of the matrix and the columns correspond to the destination. In formula number 7, the probability for choosing the next step is given. In our proposed routing, progressive ants that are generated from a source and go to the same destination node, which have the same source address and sequence number, which is called ant sequence number. Each advancing ant keeps track of the sequence of nodes it has visited. For each intermediate node, advancing ants set up reverse paths from the current nodes to the intermediate node by updating the pheromone table as described in formula number 2. When the advancing ant reaches the destination node, the destination node generates a retreating ant whose destination is the advancing ant, and the list of nodes that the advancing ant passed through is provided to the retreating ant. At each intermediate node that the backward ant reaches, it sets up a list of visited nodes just like the forward ant. When the retreating ant reaches the source node, a path is established from the source to the destination. And the source and destination nodes can now communicate with each other. This proposed method has a different policy for sending data packets and ants. In routing, when a node has multiple next hops for the destination, it randomly selects the next hop with the probability shown in formula number 8 .
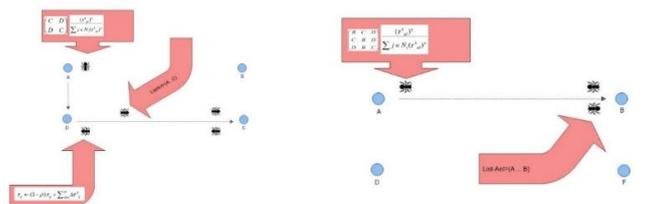

Figure 10

$$(7) \quad \frac{(\tau^k_{id})^\eta}{\sum j \in N_i (\tau^k_{id})^\eta}$$

$$(8) \quad \frac{(\tau^k_{id})^\alpha (\overline{E_i FTE^k_i})^\beta}{\sum j \in N_i (\tau^k_{id})^\alpha (\overline{E_i FTE^k_i})^\beta}$$

where E_i represents the energy level if the next node is i and FTE^k_i is the link quality and congestion factor between node k (node's current position) and neighbor i (node it wants to jump). Also known as frame transfer efficiency. The value of E_i is calculated according to formula number 9. Eiremaining is the remaining energy in the next step node and Eiinitial is the initial energy of the next step node. Neighboring nodes that have less residual energy and paths with links that have the least bad conditions are selected.

$$(9) \quad E_i = E_{iremaining} / E_{iinitial}$$

Results
NS2 Software

NS2 is an object-oriented simulation that simulates the network in a discrete, event-driven manner. This program was created and developed in Berkeley University with C++ and Otcl languages. NS2 is primarily useful for implementing local and wide area networks. NS2 was developed at UC Berkeley to simulate IP address-based networks [16]. In this simulator, network protocols such as transmission control protocol and datagram user protocol, behavior of traffic sources such as file transfer protocol, Telnet and web, queue management mechanism in routers such as Drop Tail, RED and CBQ, routing algorithms such as Dijkstra can be implemented. to be Also, in NS2, multicasting and some physical layer protocols can be implemented to simulate internal networks. The NS2 project is currently a part of the VINT project, which creates and develops tools for displaying the results of simulation, analysis and conversion of network topologies. From a user-simplified point of view, NS2 is an object-oriented TCL script interpreter that includes a list of simulation events and a library of network components and libraries for network setup and configuration. In other words, to use NS2, you write a program in Otcl script language. To set up the network, the user must write an Otcl script that creates an event register. To adjust the network topologies, the network components and functions available in the libraries and the expression of the traffic sources when starting and stopping the transfer of packets are used through the event scheduler. The word "vertical" is used to set up the network because setting up the network vertically (deeply) provides the possibility of data paths among the network components by setting the pointer from one component to the address of other components. When a user wants to create a new network component, he can easily create a new component by writing a new component or creating a composite component from the components library and establish the data flow through the components. One of the important components of NS2, along with network components, is event scheduling. Each event in NS2 is a unique identifier with a set time per packet that points to a component that causes the events. In NS2, an event scheduler keeps track of the simulation and start times of all events. Network components communicate with each other by sending packets. Although this does not cause real simulation time consumption. All network components spend part of the simulation time using packets. For example, a switch in the network that is

simulated with a 20 microseconds delay of an event for a package, the delay of each event is set to 20 microseconds in the schedule table. After 20 microseconds, the scheduler dequeues the event and sends it to the switch element, which then forwards the packet to an associated specified output element. Another use of the event scheduler is as a timer. For example, the transmission control protocol needs a timer to keep the packet transmission time. The only difference between timers and schedulers is that the timer measures the amount of time associated with a packet and assigns a specific action to that packet after a specified time has passed [16].

Simulation Environment

In this simulator scenario, the moving speed of the nodes is considered variable. Also, the number of fixed nodes and network space is 1000 meters by 1000 meters. The complete specifications of the simulation network for implementing the algorithm of the proposed method are given in Table number 1. And also in Figure 11, you can see the implemented simulation environment and the proposed routing.
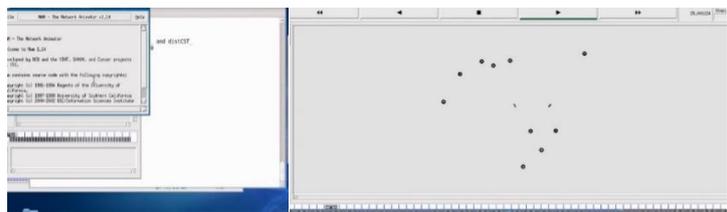

Figure 11

Simulation type	NS2-2.35
1000*1000	Environment
50	Number of nodes
(AODV&DSR)	Routing protocol
1-5-10-15-20 m/s	Speed of nodes
900s	Simulation times
802-11	Layer MAC
CBR	Traffic type
50 packet	Buffer size
by accident	Position of nodes

Table

The Evaluated Parameters

The parameters required to evaluate the effectiveness of the proposed method are as follows :
• End-to-end delay : calculates the amount of end-to-end delay in wireless networks, which is equal to the start time of sending packet j to destination i minus the arrival time of the same packet to destination i.
• Packet delivery ratio : The ratio of the total number of delivered packets to the total number of packets sent from the source node to the destination node.
• Throughput : It is equal to the total number of bytes of data transferred in the network nodes per unit of time from the time the first packet is sent to the time the last packet is received. The reason for measuring throughput in networks is that users often want to know the maximum throughput of data in a communication link or access to the network. Usually, the throughput in wireless mesh networks is kilobytes per second.
• Energy efficiency : Network energy efficiency refers to the network's ability to transmit data while minimizing energy consumption.

Data Analysis

As seen in Figure 12. The proposed protocol has a better packet delivery rate than the other two modes, and the reason for this is the selection of routes with the characteristics of the number of steps and small distance. Therefore, the length of the path is reduced compared to the other mode, and the packet reaches the destination earlier than the other protocol, and as a result, the delay is reduced.
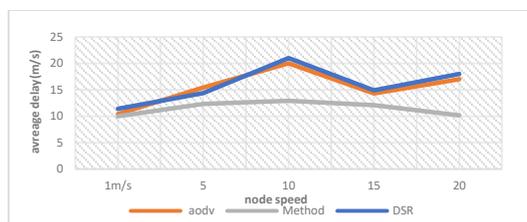

figure 12

Figure 13 shows the comparison of the proposed method and two other protocols. As mentioned in the previous section, the number of bytes correctly received by all nodes per unit of time is called throughput. Operating capacity is always considered as one of the important and basic criteria in networks. For this reason, this criterion has been studied to evaluate the proposed method. According to the diagram, the proposed method has the highest average throughput.
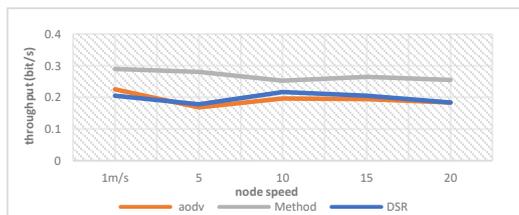

figure 13

In the field of quality of service in wireless networks, the packet delivery ratio is an important measure that shows the reliability of the network in delivering data packets to their intended destination. A high packet delivery ratio indicates that the network is reliable and can deliver data packets with minimal loss. While a low packet delivery ratio indicates that the network is unreliable and more packets are lost. According to the figure 14 above, the proposed method has a higher packet delivery rate.
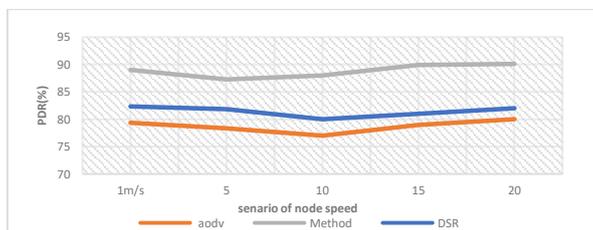

figure 14

In Figure 15, the average routing energy efficiency of the proposed method and two other protocols are compared. According to the routing diagram of the proposed method, the average energy efficiency is better than the other two protocols. which saves the energy of the nodes so that they can be stable for a longer period of time and not be destroyed. The numerical values of the parameters are given in Table number 2.
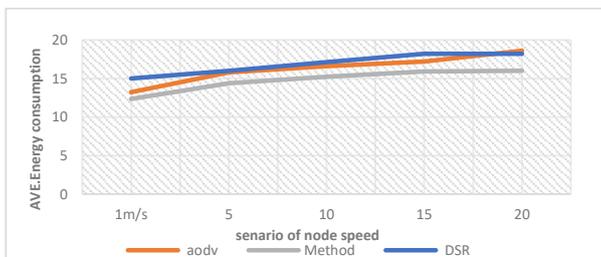

figure 15

Node speed	1m/s	5	10	15	20
Average delay AODV	10.40	15.40	20	14.33	16.98
Average delay DSR	11.40	15.40	21	14.88	17.98
Average delay Method	9.99	12.34	12.91	12.11	10.16
Throughput AODV	0.22	0.16	0.19	0.19	0.18
Throughput DSR	0.20	0.17	0.21	0.20	0.18
Throughput Method	0.28	0.27	0.25	0.26	0.25
PDR AODV	79.36	78.34	77	78.98	80.01
PDR DSR	82.34	81.84	80	80.98	82.01
PDR Method	89	87.27	88	89.9	90.1
AVE.Energy AODV	13.22	15.8	16.59	17.21	18.6
AVE.Energy DSR	15	16	17.1	18.2	18.2
AVE.Energy Method	12.34	14.39	15.21	15.9	16

Table

Discussion

In article an algorithm combining cellular automata and African buffalo is proposed [17]. In this article, the parameters of packet delivery ratio, end-to-end delay, energy consumption, packet loss and throughput are evaluated. The proposed method has a better performance than AODV in all the mentioned parameters and improves the service. In article, to improve AODV, the combination of cellular automata with hybrid genetic algorithm and African buffalo is used [19]. The simulation results showed that the proposed method performed better than AODV in parameters of packet delivery rate, end-to-end delay, energy consumption, packet loss and throughput. In article, an algorithm using African buffalo is used to improve the routing protocol of MANET [18]. In this paper, out of four scenarios, in which parameters of throughput delay, packet delivery ratio, energy consumption, and end-to-end delay are evaluated by considering node mobility, number of nodes, and simulation time. Based on the results, the performance of B-AODV is better than the standard AODV in all parameters. In article, they proposed an energy-efficient multipath routing algorithm based on the nature of ant colony search [20]. In the first scenario, the parameter of the number of hops of the AODV performs better than the ant colony-based routing algorithm. In the second scenario, the background traffic of several pairs of source and destination nodes is randomly selected in the simulation, which generates UDP traffic. And the ant colony algorithm experiences less delay compared to the AODV. Also, the ant colony routing algorithm experiences a higher packet drop ratio compared to the AODV, which makes its throughput performance lower than the AODV. Ant colony routing algorithm performs better than AODV in terms of network lifetime. In article, a hybrid algorithm, ant colony algorithm, particle swarm algorithm and a dynamic queuing mechanism have been proposed to improve the constraints of service quality parameters and minimize data loss [2]. And in terms of packet delivery rate, end-to-end delay, number of hops, routing overhead and throughput compared to ant colony algorithm, particle swarm algorithm, a combination of ACO&PSO, Enhanced-Ant-AODV and Cuckoo Search Optimization AODV (CSO-AODV). The desired investigations have been carried out. The obtained results show that the proposed HAPM routing algorithm provides better performance in almost all parameters. The number of jumps in the proposed HAPM and the combined ACO-PSO are almost the same. In article, of this study a technique based on evolutionary computation is used due to its ability to discover the complex properties of MANET [21]. A new routing metric called evolution-based routing metric is automatically generated and applied to AODV. The proposed method uses genetic programming to automatically generate a routing metric based on mobility and traffic related features. Evolution-based routing metric is used in networks with different movement and traffic patterns. Extensive simulation results show that EVO-AODV significantly improves network performance compared to state-of-the-art protocols. The proposed routing protocol based on the EVO metric produces lower routing control packets and end-to-end delay compared to the AODV, regardless of the network mobility level. It should be noted that control packets are used for route discovery and maintenance mechanisms and cause undesirable delays in packet transmission. Extensive simulation results show that the proposed approach significantly improves the packet delivery ratio. It also reduces packet drop rate, routing overhead and end-toend delay, especially in networks under moderate traffic. But it does not perform well in networks with low and high traffic.In article, HyphaNet, a new bio-inspired approach to fungal dynamics, is used to develop an algorithm for generating, optimizing and selecting routes for MANET [22]. In this new algorithm, the routing process follows the idea of attraction, where the data flow tends to travel through areas (nodes and links) of higher concentration of immobile biomass, indicating lower cost and greater availability of resources. In this model, routes are reinforced with each successfully delivered data packet, and the most attractive routes are selected by route selection heuristics. This paper proposes a solution search in the new frontiers of nature, inspiration in mushroom colonies, and the results of simulations are compared with classical AODV and ant colony-based SARA. In the first scenario, the proposed algorithm provided results very close to SARA and slightly superior to AODV in delay, overhead, throughput and delivery rate parameters. And in the second scenario, the AODV shows a better performance than the proposed algorithm and SARA, and the proposed algorithm is weak in delay and overhead parameters. In the third scenario, the proposed algorithm has a better performance than SARA and AODV in the mentioned parameters. And in the fourth scenario, the proposed algorithm works well in all parameters except the delay parameter. In general, the proposed algorithm compared to the AODV was better in almost all criteria except in the second scenario where the delay and overhead were longer. In general, the proposed algorithm performed very close to SARA. It also has important crash recovery and overhead reduction features that help system performance. In article, we propose a dynamic routing protocol based on the tabu search approach, relying on local network knowledge and intra-packet short-term memory to reduce the local minimum problem [23]. An experimental evaluation is performed, measuring the performance of the protocol under different configurations and profiles, and demonstrating its advantages. In this paper, a general mobile wireless networks are considered, which may include sensors, vehicles, drones, mobile users, etc., and the tabu dynamic location routing protocol is a tabu-based routing approach to support location-based strategies. They suggested The performance results of tabu dynamic location routing protocol compared to a classical routing algorithm based on AODV and two Greedy GCR location-based algorithms in terms of delivery rate, number of hops and number of nodes involved in sending a packet, number of sending routing packets and total We compared overhead. In most parameters, Tabu's dynamic location algorithm performs well compared to other algorithms. But in the routing overhead parameter, Greedy algorithm performs better than tabu dynamic location. In fact, for high-density networks, the performance of dynamic tabu location is improved without any overhead. Furthermore, significant improvements in terms of routing overhead (involved nodes and transmitted bytes) are obtained for the critical case of low-density networks, where dynamic tabu location provides an interesting trade-off between overhead and delivery rate. In article, it focuses on a hybrid algorithm, this algorithm is a combination of particle swarm optimization and genetic algorithm [24]. The results of the survey under the AODV to calculate the number of edges, the average battery power, the average signal strength, and the average reliability of the appropriate path between the source and the

destination show. By increasing the optimization node of PSO-GA, the parameters of data delivery rate and network lifetime decrease almost more than the binary particle swarm algorithm approach. By increasing the traffic rate, the same observation is obtained for the parameters. which shows that the proposed method works better compared to the existing methods. In article , a fuzzy logic method is planned to select the best paths in order to improve the quality of end-to-end delay services. The obtained experimental results show that the proposed fuzzy approach improves the quality of service parameters better than the existing AODV [25]. In the final stage of the investigation, the use of the combined optimization approach is suggested to select the best path. The proposed hybrid optimization is based on genetic algorithm and hill climbing algorithm. Combinatorial optimization helps to solve the local minimization problem. Hill climbing starts with an infeasible solution and continues until a viable solution is found, at which point the viable solution is returned to the genetic algorithm. The simulation results show that the proposed algorithm has a better performance in parameter, throughput than AODV and genetic-fuzzy algorithm. In article, it deals with performance evaluation of quality of service parameters in MANET using cuckoo search algorithm in AODV [26]. This proposed algorithm is based on augmenting the conventional cuckoo search technique using a request protocol. Cuckoo Search Optimization Demand Based Distance Vector Routing Protocol (CSO AODV) provides better quality of service parameters routing criteria and satisfies the constraints of quality of service parameters. The results obtained from the proposed CSO-AODV protocol are compared with ant colony optimization, particle swarm optimization, and the basic AODV, which are tested for three different conditions, i.e., mobility, scalability, and density. The simulation results show that the proposed protocol has better performance than the ant colony protocol, particle swarm optimization, and the basic AODV in congestion conditions.

Conclusion

In this article, we improved the quality of service parameters by using the ant colony algorithm, which has improved the performance of MANET. The proposed approach offers several advantages, including improved routing performance, energy consumption, and optimal path selection. This approach includes collision avoidance techniques, link quality prediction, and path maintenance techniques that mimic the ant colony algorithm. It was also discussed in the data analysis that, according to the observation, the proposed algorithm has shown better performance than the previous two methods. This algorithm, by emphasizing on optimizing the distribution of resources and improving the quality of services, can improve the performance of the network. Therefore, according to the results of the conducted researches, it is possible to use the ant colony meta-heuristic algorithm to improve quality of service parameters in MANET. This method can lead to improved performance and user satisfaction. Finally, lead to the overall improvement of MANET. The limitation of the current work in the field of security is that the packets sent from the source to the destination do not suffer from attacks of disconnection, information eavesdropping, information change, and information deception and falsification. For future work, we plan to evaluate and analyze this algorithm in terms of security so that we can achieve a more secure network.

Ethical Approval

This study did not require formal ethical approval, as it did not involve human participants or sensitive data.(Not applicable)

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References

1. Hameed, A., & Al-Omary, A. (2019, March). Survey of Blackhole attack on MANET. In 2nd Smart Cities Symposium (SCS 2019) (p. 51). Stevenage UK: IET.
2. Kumari, P. and S. K. Sahana (2022). "Swarm based hybrid ACO-PSO meta-heuristic (HAPM) for QoS multicast routing optimization in MANETs." Wireless Personal Communications: 1-23
3. Abdel-Fattah, F., Farhan, K. A., Al-Tarawneh, F. H., & AlTamimi, F. (2019, April). Security challenges and attacks in dynamic mobile ad hoc networks MANETs. In 2019 IEEE jordan international joint conference on electrical engineering and information technology (JEEIT) (pp. 28-33). IEEE..
4. Kaur, N. (2017, May). Analysis of MAODV MANET routing protocol on different mobility models. In 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT) (pp. 1815-1819). IEEE.
5. Mirza, S., & Bakshi, S. Z. (2018). Introduction to MANET. International research journal of engineering and technology, 5(1), 17-20.
6. Patel, D. N., Patel, S. B., Kothadiya, H. R., Jethwa, P. D., & Jhaveri, R. H. (2014, February). A survey of reactive routing protocols in MANET. In International Conference on Information Communication and Embedded Systems (ICICES2014) (pp. 1-6). IEEE.
7. Talbi, E. G. (2009). Metaheuristics: from design to implementation. John Wiley & Sons
8. Dorigo, M., Birattari, M., & Stutzle, T. (2007). Ant colony optimization. IEEE computational intelligence magazine, 1(4), 28-39.

9. Liang, J. J., Qu, B. Y., & Suganthan, P. N. (2013). Problem definitions and evaluation criteria for the CEC 2014 special session and competition on single objective real-parameter numerical optimization. Computational Intelligence Laboratory, Zhengzhou University, Zhengzhou China and Technical Report, Nanyang Technological University, Singapore, 635(2), 2014.

10. Ahmed, H., & Glasgow, J. (2012). Swarm intelligence: concepts, models and applications. School Of Computing, Queens University Technical Report.

11. Dorigo, M., & Blum, C. (2005). Ant colony optimization theory: A survey. Theoretical computer science, 344(2-3), 243-278.

12. Alves, D., Van Ast, J., Cong, Z., De Schutter, B., & Babuška, R. (2010, September). Ant colony optimization for traffic dispersion routing. In 13th International IEEE Conference on Intelligent Transportation Systems (pp. 683-688). IEEE.

13. Abd Elmoniem, A. M., Ibrahim, H. M., Mohamed, M. H., & Hedar, A. R. (2012). Ant colony and load balancing optimizations for AODV routing protocol. Int J Sens Networks Data Commun, 1, 1-14.

14. Tang, H., Guo, Y., & Liao, H. (2016). Research on AODV Routing Protocol based on Improved Genetic Algorithm and Ant Colony Algorithm. IJISET-International Journal of Innovative Science, Engineering & Technology, 3(5).

15. SS, V. C. (2020). A multi-agent ant colony optimization algorithm for effective vehicular traffic management. In International Conference on Swarm Intelligence (pp. 640-647). Springer, Cham.

16. Ghosh, S., Banerjee, A., Sufian, A., Gupta, S. K., Alsamhi, S. H., & Saif, A. (2023). Efficient selfish node detection using SVM in IoT-MANET environment. Transactions on Emerging Telecommunications Technologies, 34(12), e4858.

17. Hassan, M. H., Mostafa, S. A., Budiyono, A., Mustapha, A., & Gunasekaran, S. S. (2018). A hybrid algorithm for improving the quality of service in MANET. International Journal on Advanced Science, Engineering and Information Technology, 8(4), 1218-1225.

18. Hassan, M. H., Mostafa, S. A., Mohammed, M. A., Ibrahim, D. A., Khalaf, B. A., & Al-Khaleefa, A. S. (2019). Integrating African Buffalo optimization algorithm in AODV routing protocol for improving the QoS of MANET. Journal of Southwest Jiaotong University, 54(3).

19. Hassan, M. H., & Muniyandi, R. C. (2017). An improved hybrid technique for energy and delay routing in mobile ad-hoc networks. International Journal of Applied Engineering Research, 12(1), 134-139

20. Sharma, A., & Kim, D. S. (2019, January). Robust bio-inspired routing protocol in manets using ant approach. In International Conference on Ubiquitous Information Management and Communication (pp. 97-110). Cham: Springer International Publishing.

21. Hasdemir, S., Yilmaz, S., & Sen, S. (2019). A novel multi-featured metric for adaptive routing in mobile ad hoc networks. Applied Intelligence, 49(8), 2823-2841.

22. da Costa Bento, C. R., & Wille, E. C. G. (2020). Bio-inspired routing algorithm for MANETs based on fungi networks. Ad Hoc Networks, 107, 102248..

23. Bujari, A., De Giovanni, L., Palazzi, C. E., & Ronzani, D. (2021). Location dynamic tabu routing protocol for MANETs. Mobile Networks and Applications, 26(5), 2055-2065.

24. Krishna, S. R. K. M., Ramanath, M. B. N. S., & Prasad, V. K. (2018). Optimal reliable routing path selection in MANET through hybrid PSO-GA optimisation algorithm. International journal of mobile network design and innovation, 8(4), 195-206.

25. Kuppuchamy, N. K., Manikandan, K. P., & Geerthik, S. (2021). Qos improvement using hybrid genetic algorithm based AODV in manet. Turkish Journal of Computer and Mathematics Education, 12(8), 2128-2135.

26. Mandhare, V. V., Thool, V. R., & Manthalkar, R. R. (2016). QoS Routing enhancement using metaheuristic approach in mobile ad-hoc network. Computer Networks, 110, 180-191.

27. Adam, S. M., & Hassan, R. (2013). Delay aware reactive routing protocols for QoS in MANETs: A review. Journal of applied research and technology, 11(6), 844-850.

28. Fatemidokht, H., & Kuchaki Rafsanjani, M. (2018). F-ant: an effective routing protocol for ant colony optimization based on fuzzy logic in vehicular ad hoc networks. Neural Computing and Applications, 29(11), 1127-1137.

29. Ostfeld, A. (Ed.). (2011). Ant Colony Optimization: methods and applications. BoD–Books on Demand.

30. Socha, K., & Dorigo, M. (2008). Ant colony optimization for continuous domains. European journal of operational research, 185(3), 1155-1173.